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Performance of a Small Anode Germanium Well detector

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ABSTRACT

The performance of Small Anode Germanium (SAGe) Well detector [1] has been evaluated for a range of sample sizes and geometries counted inside the well, on the end cap or in Marinelli beakers. The SAGe Well is a new type of low capacitance germanium well detector manufactured using small anode technology. The detector has similar energy resolution performance to semi-planar detectors, and offers significant improvement over the Coaxial and existing Well detectors. Resolution performance of 0.75 keV Full Width at Half Maxiumum (FWHM) at 122 keV γ-ray energy and resolution of 2.0–2.3 keV FWHM at 1332 keV γ-ray energy are guaranteed. Such outstanding resolution performance will benefit environmental applications in revealing the detailed radionuclide content of samples, particularly at low energy, and will enhance the detection sensitivity resulting in reduced counting time. This paper reports the counting performance of SAGe Well detector for range of sample sizes and geometries and how it compares to other detector types.

1. Introduction

The Small Anode Germanium (SAGe) Well detector is a new commercially available type of low capacitance germanium well detector [1]. The low detector capacitance associated with the small anode technology gives the SAGe Well similar resolution performance to semi-planar detectors [2,3] and superior low and medium-energy resolution performance compared to existing Traditional Well and coaxial detectors. The SAGe Well detector is suitable for environmental counting over an energy range of 20 keV–10 MeV. It also offers application for nuclear power radio-chemistry for low, medium, and high count rate sample including ultra-low activity sample counting and a variety of physics applications that require higher efficiency.

The SAGe Well detector is a p-type elongated semi-planar detector type with a re-entrant well in the front face as shown in Fig. 1. The boron-implanted p^+ signal contact covers a surface area of approximately 200 mm^2 on the rear face of the device. The entire remaining area, with the exception of the 1060 mm^2 annular junction area, is covered by the lithium-diffused n^+ contact. In order to create a good physical contact with these electrodes, indium and gold were used as ohmic contacts to the n^+ and p^+ electrodes, respectively. The thin lithium (approximately 50 μm thickness) diffused contact inside the well, combined with a thin-walled aluminum insert in the detector end cap (0.5 mm on the sides and a 1 mm thick at the bottom) provide good low-energy response, allowing spectroscopy down to 20 keV. The lithium contact on the outer surface of the detector is approximately 0.5 mm thick. The useful energy range for sources outside of the well is limited to 40 keV and up. The SAGe Well detector is fabricated with a blind hole, leaving at least 20 mm of active detector thickness at the bottom of the well. The well counting geometry approaches 4π thereby providing the maximum absolute counting efficiency for samples in the well.

In this article the performance of SAGe Well detectors has been evaluated relative to other detector types for a range of sample sizes and geometries counted inside the well, on the end cap and in Marinelli beakers in terms of their detection sensitivity. The three detectors selected for comparison are the Traditional Well, semi-planar and coaxial detectors with electrode structure as shown in Fig. 2 [6]. Considered first is the achievable sensitivity performance of SAGe Well and how it compares with existing Traditional Well detectors for samples placed inside the well. Secondly, the sensitivity of SAGe Well detector for counting filter paper and large volume samples was determined and compared with semi-planar and coaxial detectors. Both the semi-planar and coaxial detectors have shapes that are approximately cylindrical. While semi-planar detectors are known to be wider than they are long and offer excellent energy resolution at low energies, coaxial detectors are the most common type of germanium detector for wide area of applications. The description of the detector models selected for this study including their active volumes and how they compare with SAGe Well detector are provided in the subsequent sections.

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2. Energy resolution performance

Energy resolution performance of the SAGe Well detectors was measured with a mixed gamma radioactive source positioned on the detector axis, nominally 10 cm from the end cap face of the detector. The energy resolution, defined as the FWHM, measured for two different SAGe Well detector models; GSW120 with 16 mm well and GSW275L with 28 mm well is shown in Fig. 3. The SAGe Well detector offers two major advantages for in-well counting. First, the vastly improved resolution greatly enhances detection sensitivity for nuclides particularly at low energies. Second, the optional 28 mm well size is the largest of any germanium well detector in the industry and SAGe Well detector design is such that energy resolution is independent of well size. This larger well model has the same excellent energy resolution as smaller wells as shown in Fig. 3. Fig. 4 is an overlay of resolution performance of SAGe Well detector with other detector types. The curves shown in this figure are fit to experimental data from three detectors in order to account for the variation in the resolution spread in the measured data. The results clearly demonstrate that SAGe Well detectors have similar resolution performance to semi-planar detectors [2], and offer significant improvement over coaxial detectors [5] and existing well detectors [4].

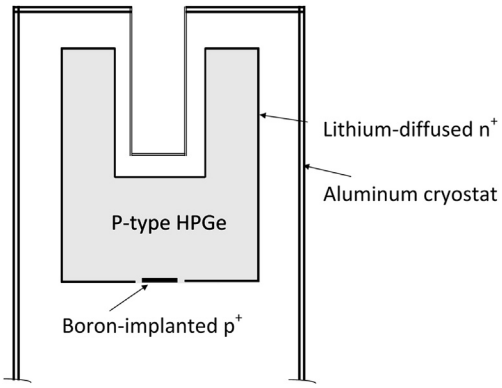

Fig. 1. Schematic drawing of SAGe Well detector inside aluminum cryostat. (Drawing is not to scale).

3. Detection sensitivity of SAGe Well detector

This section presents how the improved resolution performance of SAGe Well detector translates into increased sensitivity.

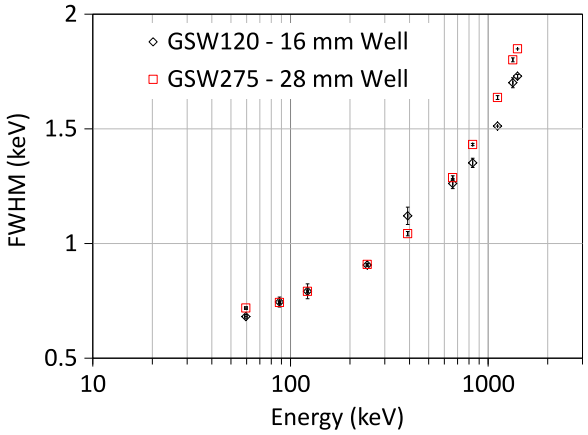

Fig. 3. Measured energy resolution (FWHM) as a function of energy for two SAGe Well models. The measured resolution at 1332 keV energy is 1.70 ± 0.02 keV and 1.80 ± 0.01 keV, for GSW120 and GSW275L SAGe Well detectors, respectively.

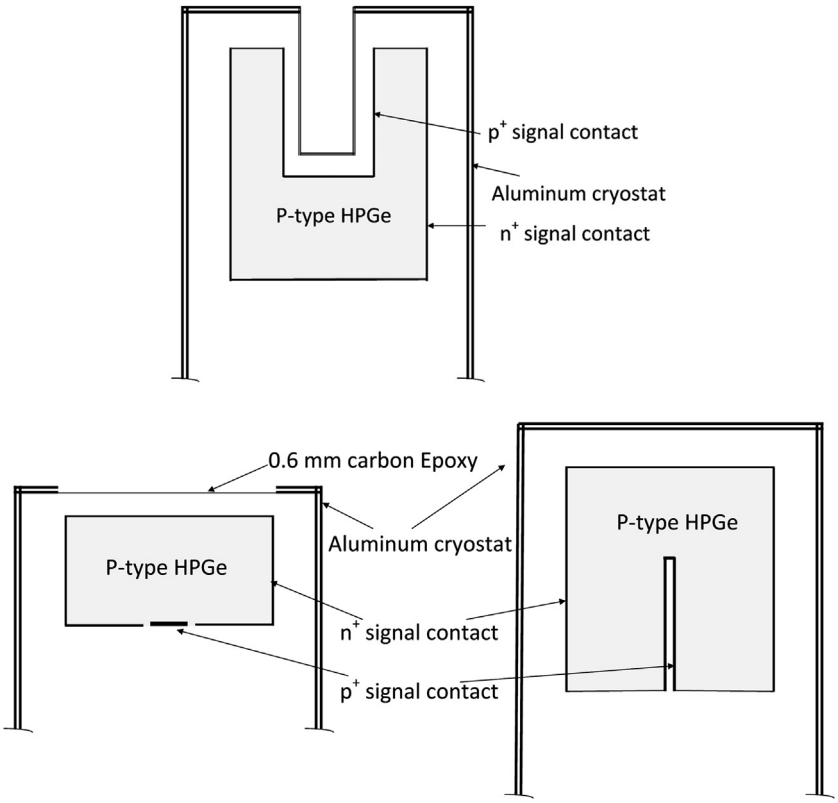

Fig. 2. Schematic drawing of Traditional Well (top), low-capacitance semi-planar detector (bottom Left) and coaxial detector (bottom right) inside aluminum cryostat [4,2,5]. The n and p signal contacts are typically diffused lithium and implanted boron respectively. (Drawing is not to scale).